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for

Skylab Experiment T025

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REPORT FOR SKYLAB EXPERIMENT T025 (Dudley
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I Introduction

The airlock coronagraph (T025), being a simple but versatile instrument, was to be employed for a number of distinct observing programs. (Its versatility was exploited by a number of other investigators for photographing the zodiacal light, the Gegenschein, etc....). The distinct observing programs of T025 were three in number:

- 1) the atmospheric scattering program,
- 2) Kohoutek photography,
- 3) the spacecraft contamination problem.

This report covers the problems encountered in the operation of the experiment, the quantity and quality of the data retrieved for each of the three programs, a status report of the data reduction, and the priority and direction of the analysis being pursued under this contract. Since the operational difficulties had varying degrees of impact on each of the three programs, we first describe those problems and then relate their impact on the objectives, the data gathered, and the scientific value of the results in each area of investigation.

II Difficulties and Anomalies

In chronological order, we describe here four major operational difficulties which have affected the original observing program of T025. First, the loss of the meteoroid shield during launch made the solar airlock unusable. Since the coronagraph by its very nature is a solar oriented instrument, another means had to be devised for mounting it. Thus, a relatively large amount of observing time (30 to 40 viewing opportunities) was reduced to a few observations during an EVA. The second difficulty arose in modifying the coronagraph for EVA operation. In order to allow the coronagraph to be manually pointed, a 6000Å long pass filter was inserted in the coronagraph occulting disc. Thus, the red end of the visible spectrum had to be sacrificed. Third, the shutter speed extension knob, required so that the suited crewman could change exposure times, was not seated properly during the first SKYLAB III EVA (Thanksgiving Day) resulting in only six (6) photos out of the required set of 40 for atmosphere observations. And last, upon inspection of the developed film, it was found that all photos (except the six mentioned above) were out-of-focus.

A discussion of the last mentioned malfunction is in order - the others having been thoroughly discussed in our monthly reports. The out-of-focus condition is confined to all photos employing the Nikon 02 camera. Five experiments were affected. The lens was not at fault since it is hard focused at infinity and performed well on other on-board cameras. We also conducted a series of tests which conclusively proved that an adapter ring was not erroneously mounted between the lens and camera body.

The most plausible explanation at this time is that the pressure plate which maintains the film in the focal plane was somehow disabled. As will be mentioned in a later section, we presently have sufficient knowledge of the condition to attempt a one dimensional reconstruction of the out-of-focus photographs.

The Atmospheric Program

The atmospheric program employs the coronagraph in order to observe the earth's atmosphere during periods near twilight in the direction near (from 4° to 10°) the sun. Observations made close to the sun are much more sensitive for the detection of aerosol than those made in other directions. Furthermore, the analysis of the data is greatly simplified when the sun is above the horizon - a situation which can only be viewed with a coronagraph. The initial observing program, based on observations through the solar airlock, outlined 30 sequences of forty photographs. Most of these sequences employed filters selected for their sensitivity to the ozone and aerosol structure with a few sequences made in color. The goal of this program was to survey and monitor the atmospheric aerosol structure. In particular, we wanted to photograph the limb over differing geography, oceans, and industrial sites and at various latitudes in order to look for aerosol effects and also to relate aerosol changes with solar activity and meteoroid showers. Analysis of the data was to be based on a single-scattering model of the earth's atmosphere. Such a model would be adequate to explain relative changes in atmospheric aerosol content.

The loss of the airlock greatly curtailed the survey aspect of the program. On Thanksgiving Day, six photographs of the earth's limb were taken over the southern Atlantic Ocean. The shutter speed extension knob failure limited the data to two pictures in white light, two pictures at 2500\AA and two pictures at 3600\AA . The atmospheric ozone structure is clearly seen in the 2500\AA picture (see Figure 1). The longer wavelength photos which are much more sensitive to aerosol structure, were not obtained on this pass. The experiment was performed again on February 3 over the northern Pacific Ocean. For this sequence of 40 photos we have both ground based and satellite data on the prevailing meteorological conditions. Upon development of the flight film, we discovered the out-of-focus nature of this sequence of photographs. An example is provided by Figure 2 for which the same camera settings and filters were employed as those used in Figure 1. Figure 3 shows a white light photograph from the out-of-focus sequence. The larger size of the solar disc in Figure 3 compared to Figure 2 gives an estimation as to the "circle of confusion" in the out-of-focus photographs.

The six photographs which are in focus are unique and contain valuable information on the ozone structure. Furthermore, after consultation with the image processing laboratory at NASA's Jet Propulsion Lab and with Dr. Sawchuk, University of Southern California, we believe the out-of-focus photographs can be restored to a great extent, at least in the direction radial to earth. The longer wavelength photos (5500\AA) are particularly sensitive to aerosol structure, but the full sequence in six colors is helpful in separating the molecular and aerosol components of the atmosphere.

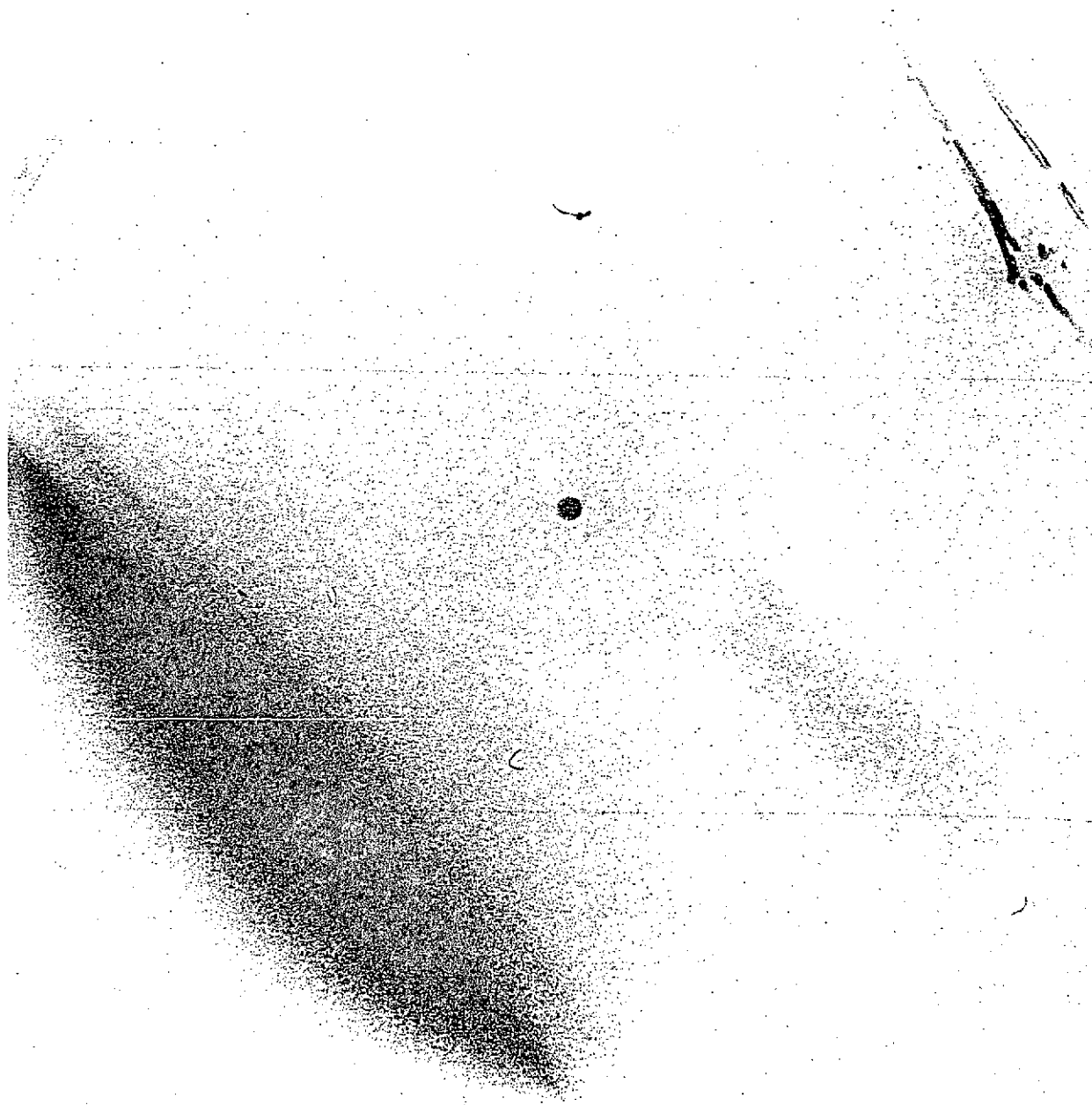


Figure 1



Figure 2

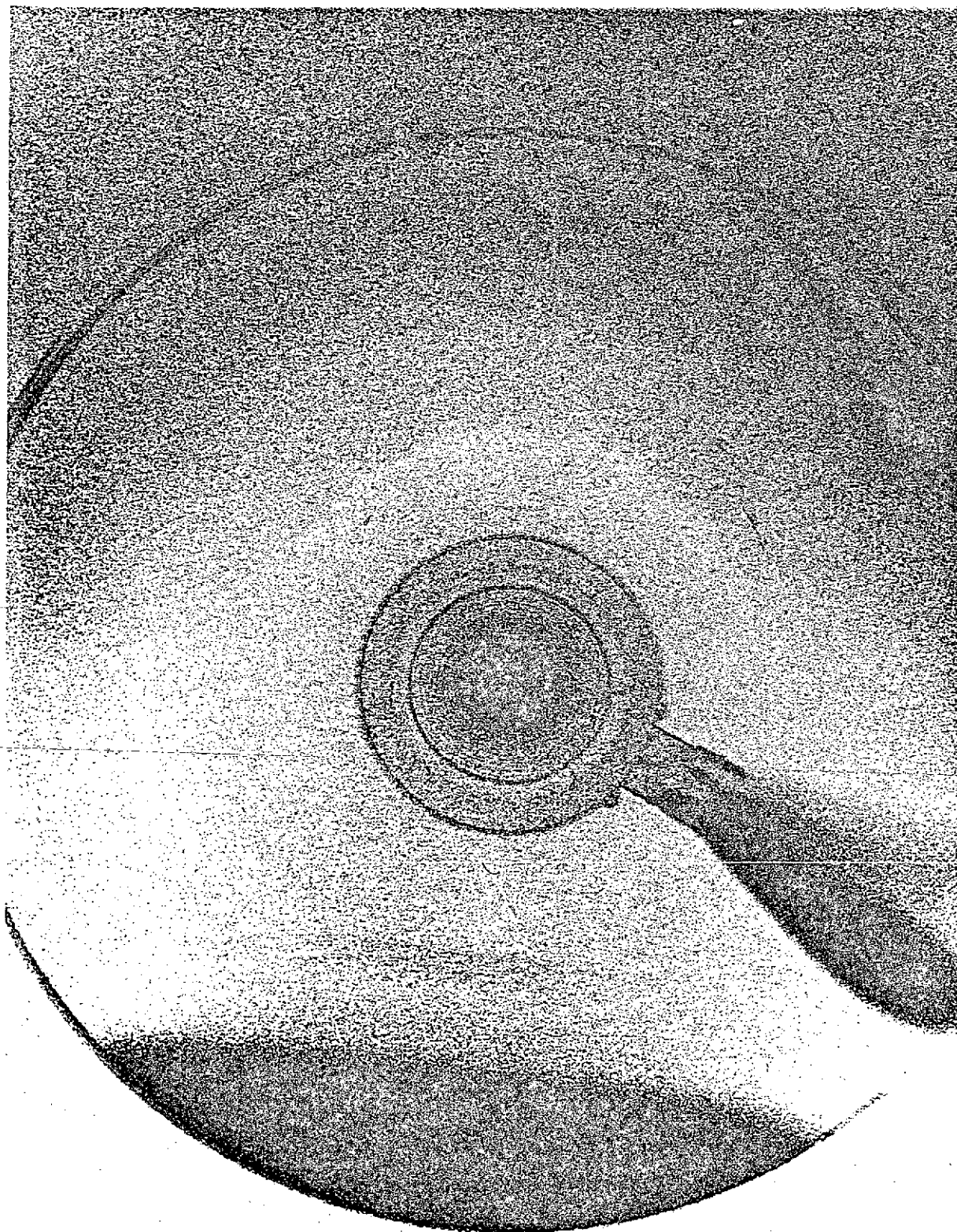


Figure 3

Also the analysis of the six good photographs along with those that might be restored will require a more exact treatment than originally envisioned for the following reason. In the original survey approach, only relative variations of the limb profiles were to be analyzed in terms of aerosol variations. In the present situation, one must work on an absolute basis. Fortunately, we have calibration wedges on all film strips. We have just completed a vignetting analysis, and the flight filters have been returned for post flight deterioration checks. The observational parameters are all available then for an absolute study.

The area of analysis that has been affected the most by the limited quantity of data is the theoretical approach to modeling the earth's atmosphere. We have just completed a computer code which yields the brightness profile of the earth's limb in the single scattering approximation. Since we must now work on an absolute basis, multiple scattering must be taken into account. For problem geometries such as encountered in spacecraft observations, this has been an agonizing problem. Only recently have Monte Carlo techniques been employed to do this calculation and very large amounts of computer time have been required. It is in this area that we feel the reduced Skylab T025 data has provided the impetus to examine the special problem of coronagraph observations in greater detail. We think that by employing and expanding a method of approximation due to Sobolev in the early 1960's we can analyze coronagraph observations to sufficient accuracy for the upper levels of the atmosphere. Specifically, we are now constructing models of the earth's limb taking single scattering into account exactly and assuming the multiple scattering

component to be isotropic. We believe such a technique to be reliable for describing the earth's limb radiation down to at least heights of 30 Km (2500Å) or 10 Km (7000Å) depending on wavelength. Proof of the method will be a comparison with the Monte Carlo calculations. Our analysis - which does not involve large amounts of computer time - would be ideally suited for near real-time data reduction of spacecraft horizon observations.

Our goal is to prove the power of the coronagraph technique for aerosol monitoring. The space program affords the long awaited opportunity to monitor aerosols on a global scale and for extended lengths of time. If the Skylab data can confirm the ability of the coronagraph technique to make such measurements and provide a testing ground for reduction techniques, experiment T025 will be a major success.

In summary, the atmospheric investigation for the duration of this contract will include laboratory studies of filter deterioration, scattering of light by particulates, and most importantly the reconstruction of the out-of-focus condition encountered on Skylab. The latter effort is necessary for input to image processing codes to "defocus" the majority of our photos. Such results may prove of interest to other Skylab investigators who encountered the problem of Nikon 02. Another problem area also exists, The EVA mode of observation introduced problems of scattered light from the external spacecraft structure. These must be identified and removed from the photos. The theoretical aspect of the investigation will be directed to radiative transfer studies which include multiple scattering so as to compare and explain the limb observations, techniques to extract the aerosol and ozone distribution directly (the inverse problem) and the restoration of

the out-of-focus photos.

It is evident that such a program may not be completed by the duration of this contract. However, by that time we hope to have a strong scientific justification for the use of the coronagraph technique of aerosol detection not only for terrestrial observations but for other planets as well.

III Comet Kohoutek Observations

Comet Kohoutek was to be observed in 13 colors near perihelion with the EVA mounted T025 coronagraph. These observations were expected to provide a spatial multicolor record, particularly of the OH, CN, C₂, and Na emissions, of the comet near its perihelion point. The narrow band observations of the comet's reaction to the more intense solar radiation and gravitational forces near perihelion is of major importance in order to determine the physical makeup of the comet and the mechanical forces acting to hold it together. Further, in order to better define the exposures needed for the Skylab observing program, ground level photographic observations were made from Haleakala, Hawaii with filters, cameras, and film similar to Skylab equipment. These proved useful not only for our own observing program, but for other Skylab Investigators as well.

Observations of the comet were made on EVA 2 and 3 using the filters listed in Table I. Unfortunately, the Nikon 02 camera body was used with the resulting out-of-focus condition previously described. The comet images were consequently greatly enlarged and the image irradiation diluted by a factor of at least 100. The effect was to reduce the resulting image signal to the noise level of the photographic record, and in fact visual inspection with a 10x eye piece failed to detect a comet image. The observations however are not considered a complete loss, as it is expected that by a careful analysis of the 84 Skylab frames obtained during the two EVAs, either Kohoutek will be statistically detected, or that at least an upper limit can be placed on the comet's brightness.

TABLE I

T025 SKYLAB DATA SUMMARY

$\lambda_0(\text{\AA})$	Filter $\Delta\lambda(\text{\AA})$	Comet Purpose	Atmosphere in-Focus # Frames	Skylab out-of-Focus # Frames	Comet Skylab out-of-focus # Frames	Comet Hawaii # Successfull Days
No Filter			2	4	6	20
2530	300	Continuum	2	6	4	
2800	300			6	4	
3100	60	OH lines			6	
3250	60	OH continuum		6	6	
3361	60				4	
3600	300	Continuum	2	6	4	2
3873	30	CN lines			6	6
3940	25	CN continuum			4	2
4262	20	CO ⁺ lines			4	1
4430	100	Dust		6	4	1
4700	60	C ₂ lines			4	5
4900	60	C ₂ lines			4	3
5000	300	Continuum				2
5500	200	Continuum		6	4	6
5890	30	Na lines			4	4
6000	Short-pass	Continuum			6	
6000	Long-pass	Continuum				6

This work requires the original flight film for maximum information retrieval, and must await our receipt of these films and their subsequent digitization and analysis. Because of the higher priority of other (atmospheric) aspects of our program, it is not expected that the Skylab comet film will be reduced until the end of the year.

The ground based observations were made at the 3000 m. high site at Haleakala on 20 clear nights between 14 November and 12 December 1973 in eleven colors between 3600Å and 7000Å. These observations were made using the F/2 55mm f.1. UV Flight Type lens, the F/1.2 55mm f.1. visible wavelength Flight Type lens, F/5.6 350mm f.1 commercial lens, and a F/5.6 400 mm f.1 commercial lens, with Nikon 35mm camera bodies, mounted on a portable equatorial mount. Over 1000 photographs of all types were taken and reduced to provide current exposures to Kohoutek Comm Center, Houston for use in the Skylab-Kohoutek Program. The collected photographs also represent a comprehensive record of pre-perihelion comet and because of the similarity in filters, cameras, and lenses with those used in other comet experiments on Skylab, they are particularly interesting.

The 20 days of ground based observation in white light, complement the Skylab S233 white light observations made with the hand held f/1.2 55mm visible lens and Nikon body, and are expected on reduction to provide an absolute brightness morphology of the comet before perhelion. The multi-color observations, listed in Table I, complement the S063 multicolor Kohoutek data made with similar filters, camera, and f/2. UV lens. Our multicolor observations including the strong emissions in Na (5890), C₂ (4700), and CN (3873) were limited by the faintness of the comet and

were not photographed until after 07 December. The Haleakala observations show very strong emissions in CN, C₂, and Na. The strength of these lines is attested to by the lack of brightness of the CO⁺ and continuum measurements.

Table II is a list of the more valuable observations made at Haleakala. The reduction of these observations is now under way, although delayed by the failure of the Dudley microdensitometer. Digitization of the more important frames was accomplished at PTD JSC in May and are now being analyzed. The analysis, being supplemented by further digitized frames when the Dudley microdensitometer is returned to service, is expected to continue through November.

It should be noted that the reduction of the ground based frames is somewhat difficult as several factors must be taken into account. Besides the normal consideration of spectral sensitivity of the instrumental system (which has already been generally determined), corrections must be applied for atmospheric transmission, sky brightness, and image motion. In general the white light photographs provide an adequate image so that isophotes and general morphological history can be studied, while the color photographs suffer more from image motion. It is expected that the absolute integrated brightness will be derived from these color frames, with only a few providing morphological information.

TABLE II

SUPPORTING GROUND BASED OBSERVATIONS

<u>Date</u>	<u>White Light</u>	<u>Na</u> <u>5890</u>	<u>C2</u> <u>4700</u>	<u>CN</u> <u>3873</u>	<u>Continuum</u> <u>5500</u>	<u>Continuum</u> <u>6000</u>
14 Nov.	x					
15	x					
16						
17	x					
18	x					
19	x					
20						
21						
22	x					
23						
24						
25						
26						
27						
28						
29						
30						
1 Dec.						
2						
3	x					
4	x					
5	x					
6	x					
7	x					
8						
9						
10						
11						
12						
13	x					
14	x		x	x	x	x
15	x			x	x	x
16	x	x	x	x	x	x
17	x	x	x	x	x	x
18	x	x	x	x	x	x
19	x	x	x	x	x	x
20						

IV Local Contamination in the Spacecraft Environment

The original objective in this area was to photograph small particulates immediately in the neighborhood of the spacecraft. By making a series of photographs at various focus settings, individual counts of in-focus particles would yield the number density as a function of distance from the spacecraft. With the coronagraph, particles of a few microns in radius could be detected because of the strong source of illumination (the sun) and the forward scattering property of small particles. Because of the inaccessability of the airlock, this area of investigation was not pursued.

A delay at Houston in preparing copies of our flight film has delayed detailed inspection of the original out-of-focus photographs. In mid May we made use of the Houston facility to digitize some of the flight film photographs. At this time it was noted that particles may be apparent in the field due to the fact that the out-of-focus condition yields an effective focus at 45 inches from the camera. When the investigation begins using the original flight film, local particulate contamination will be recorded as it is identified. If a sufficient body of data is generated, we may begin a size distribution study of these particulates. The amount of effort put forth in such an endeavor will be governed by the work load generated in the other areas. It is necessary that the original flight film be used because of dust and dirt images produced on the second generation negatives by contaminants introduced during the copying process. These spurious images make it difficult to tell the real particles from the reproduced laboratory contaminants.

We take this opportunity to thank Mr. Schneider, Mr. Kleinknecht, the crew, and the NASA support we have received in keeping this experiment operational in the face of many unanticipated difficulties. Even with the limited data obtained, we presently feel that T025 can make a significant scientific contribution particularly in the area of aerosol remote detection methods.